GEOG 5075.01 Selected Topics in Geography: Novel Remote Sensing and Geospatial Applications

Final Project Report

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Masters in Geographical Information Systems

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Project Title: Vegetation Canopy and Green Space Analysis Using LiDAR Data in Conroe, TX

Date: 12/12/2024

INTRODUCTION

Green spaces, like parks, forests, and areas with trees, are essential parts of any urban environment. They provide many benefits, such as improving air quality, reducing city temperatures, and offering recreational areas for people. One important feature of green spaces is the vegetation canopy, which is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Canopies help create shade, trap pollutants, and reduce noise, making urban areas more livable.

In recent years, cities have grown rapidly, leading to a decrease in green spaces and an increase in buildings and infrastructure. This change often results in environmental issues, such as the urban heat island effect, where city areas become much warmer than surrounding rural areas due to the concentration of buildings, roads, and lack of trees. Urban heat islands can have negative effects on people's health and well-being, especially in densely populated neighborhoods. Because of these challenges, it’s important for urban planners and local governments to understand the current state of green spaces and canopies in cities so they can make informed decisions about preserving and expanding them.

In this project, I will use LiDAR (Light Detection and Ranging) data to study vegetation canopy and green spaces in a specific urban area. LiDAR is a remote sensing technology that uses laser light to create highly detailed, 3D images of landscapes, including buildings, trees, and other natural features. LiDAR data is valuable for this type of project because it provides precise information about the height, shape, and structure of objects, which helps distinguish different types of vegetation and analyze the canopy cover. By analyzing this data, I aim to identify areas with good canopy coverage, as well as regions where green spaces are lacking.

The purpose of this project is to support urban planning efforts by providing information about existing green spaces and suggesting areas where more vegetation could be added. This analysis will help make cities healthier, cooler, and more environmentally friendly. Ultimately, the findings from this project can guide decisions to create a balanced city landscape that includes both buildings and natural areas, benefiting residents and the environment alike.

LITERATURE REVIEW

Urban green spaces, including parks, trees, and vegetation, play a crucial role in making cities more sustainable and improving the quality of life for their residents. Several studies have highlighted the benefits of green spaces, such as cooling urban areas, improving air quality, supporting biodiversity, and enhancing mental and physical well-being. This literature review explores recent studies on the importance of vegetation canopies in urban areas and the use of LiDAR technology to analyze these green spaces effectively.

Benefits of Urban Green Spaces and Vegetation Canopies

Urban green spaces and tree canopies help reduce the urban heat island effect, a phenomenon where urban areas become significantly warmer than rural areas. This warming effect occurs due to the high concentration of concrete, asphalt, and other heat-absorbing materials in cities, combined with a lack of trees and vegetation. Studies show that tree canopies provide shade and release moisture through a process called evapotranspiration, which helps cool the air around them (Zhang & Qiu, 2012). This cooling effect is especially important in densely populated cities, where high temperatures can lead to heat stress and health problems, particularly for vulnerable groups like children and the elderly.

Additionally, urban vegetation improves air quality by trapping dust, absorbing pollutants, and releasing oxygen, which contributes to better respiratory health for city residents. A study by Nowak et al. (2006) estimated that urban trees in the United States remove approximately 711,000 metric tons of air pollution each year, providing an estimated $3.8 billion in value. These benefits make urban canopies a valuable resource for cities aiming to improve public health and environmental sustainability.

Using LiDAR Technology to Map and Analyze Urban Vegetation

LiDAR (Light Detection and Ranging) technology has become an essential tool for studying vegetation canopies and green spaces in urban areas. Unlike traditional remote sensing methods, LiDAR provides highly accurate, 3D data on the structure, height, and density of vegetation. This allows researchers to classify different types of vegetation, assess canopy coverage, and measure tree heights, which are crucial for understanding the health and distribution of green spaces.

Hopkinson (2007) conducted a study using LiDAR data to model vegetation structure and measure canopy gaps in forested areas. Their research demonstrated that LiDAR could effectively

capture detailed canopy information, making it useful for both urban and natural settings. This approach can be applied in urban environments to map tree canopies and analyze green space distribution, helping city planners make decisions about where to preserve or expand vegetation (Hopkinson, 2007).

In another study, Zhang and Qiu (2012) used LiDAR data combined with hyperspectral imagery to classify individual tree species within an urban forest. This study demonstrated that LiDAR could not only map tree canopies but also differentiate between species based on their structure and height. This kind of detailed analysis can help cities manage their tree inventories, plan for diverse plantings, and monitor tree health. Alonzo et al. (2016) demonstrates how high-resolution LiDAR data can be used to map the structure and functions of urban forests, including canopy height and density, which are critical for understanding the ecological benefits of urban green spaces

Importance of Green Space Analysis for Urban Planning

Understanding the current distribution and density of vegetation canopies is essential for urban planning. By identifying areas with insufficient green space, city planners can develop strategies to increase tree planting, add parks, and improve public access to nature. Several studies have highlighted the need for such analyses, emphasizing the positive impacts of green spaces on urban residents' mental health, physical health, and community well-being (Wolch et al., 2014).

Research by Wolch et al. (2014) underscores the concept of "green equity," which suggests that all city residents should have access to green spaces, regardless of their socioeconomic status. The study showed that areas with low-income populations often have fewer parks and green spaces, leading to inequalities in health outcomes. LiDAR-based green space analysis can help identify such inequities and provide data to guide interventions that make green spaces more accessible to everyone.

DATA DESCRIPTION

For this analysis, I will use high-resolution LiDAR data obtained from the [https://apps.nationalmap.gov/downloader/]. The dataset captures the detailed topography of the area, including the height and structure of vegetation, which is essential for accurate canopy classification. Additional data such as land cover maps and hydrological data may be incorporated to provide context and improve classification accuracy. I will use ArcGIS pro for this study.

METHODOLOGY

This section outlines the detailed steps taken to analyze the vegetation canopy and green spaces in Conroe, TX, using LiDAR data and ArcGIS Pro.

a) Data Preprocessing

Objective: Prepare the LiDAR data for analysis by filtering non-relevant points and isolating vegetation.

i) **Importing LiDAR Data**:
   - The raw LiDAR data was imported into **ArcGIS Pro** using the LAS Dataset.
   - This dataset included elevation and intensity information for each LiDAR point.

ii) **Filtering LiDAR Points**:
   - Using the **LAS Dataset Properties**, non-vegetation points were filtered out by selecting only the vegetation classifications. Points were grouped as:
     - **Low Vegetation**: Class 3
     - **Medium Vegetation**: Class 4
     - **High Vegetation**: Class 5
   - This step excluded points representing ground, buildings, and noise.

iii) **Creating Vegetation Layers**:
   - Separate layers for **low, medium, and high vegetation** were created using the **Make LAS Dataset Layer** tool. This allowed further processing to focus exclusively on vegetation.

b) Vegetation Intensity Raster Creation

Objective: Convert LiDAR intensity values into a raster format for analysis.

i) **LAS Dataset to Raster Tool**:
   - The **LAS Dataset to Raster** tool was used to convert the filtered LAS datasets into raster layers, representing intensity values.
   - Key settings:

- **Value Field**: Intensity (measuring the reflectivity of surfaces).
- **Interpolation Type**: Binning (to group points into a grid).
- **Cell Size**: 10 meters (chosen based on data density and study area size).
- **Output Data Type**: Floating point (to preserve the intensity range).

ii) **Resulting Rasters**:

- Separate rasters were created for low, medium, and high vegetation intensity, representing their spatial distribution across the study area.

c) Reclassification of Intensity Raster

Objective: Categorize the intensity values into meaningful vegetation density classes.

i) **Reclassification**:

- The **Reclassify** tool was applied to the vegetation intensity raster.
- Intensity values were divided into three classes using natural breaks (Jenks):
  - **Green (Low Intensity)**: Representing dense vegetation.
  - **Yellow (Medium Intensity)**: Representing moderate vegetation.
  - **Red (High Intensity)**: Representing sparse vegetation or bare areas.

ii) **Output**:

- The reclassified raster displayed the intensity values categorized into vegetation density classes for clear visualization and further analysis.

d) Calculation of Vegetation Percentage

Objective: Quantify the percentage of densely vegetated areas (Green, Low Intensity).

i) **Raster Attribute Table**:

- The **Attribute Table** of the reclassified raster provided pixel counts for each class.
- The total pixel count for each class was recorded.

ii) **Area Calculation**:

- Each pixel represented 100 square meters (10m x 10m cell size).

- The total area of densely vegetated areas was calculated by multiplying the number of pixels in the "Green" class by 100.

iii) **Percentage Calculation**:

$$\text{Percentage of Green Areas} = \left(\frac{\text{Green Area Pixels}}{\text{Total Pixels}} \right) \times 100$$

e) Mapping Vegetation Density

Objective: Create a visual representation of vegetation distribution.

i) **Symbology**:
   - The reclassified raster was symbolized using a color ramp:
     - Green for low intensity (dense vegetation).
     - Yellow for medium intensity.
     - Red for high intensity (sparse vegetation).

ii) **Overlay with City Boundary**:
   - The raster was clipped to the Conroe City boundary using the **Extract by Mask** tool to ensure the analysis focused on the study area.

iii) **Final Map**:
   - A map was generated showing the distribution of vegetation density across Conroe City, with a legend and scale bar for interpretation.

f) Validation and Interpretation

Objective: Ensure the results align with real-world patterns and draw actionable insights.

i) **Validation**:
   - The resulting map and pixel counts were cross-checked with aerial imagery to validate the accuracy of vegetation distribution.
   - Low intensity (dense vegetation) areas were primarily located near natural features, such as **Lake Conroe** and forested zones.

ii) **Interpretation**:

- Urban areas with less vegetation (red zones) were identified as potential targets for green space development.
- The spatial pattern highlighted the urban core's lower vegetation density compared to the city's periphery.

Flowchart of Methodology

1. **LiDAR Import** → 2. **Vegetation Filtering** → 3. **Intensity Raster Creation** → 4. **Reclassification** → 5. **Percentage Calculation** → 6. **Mapping and Interpretation**

RESULTS

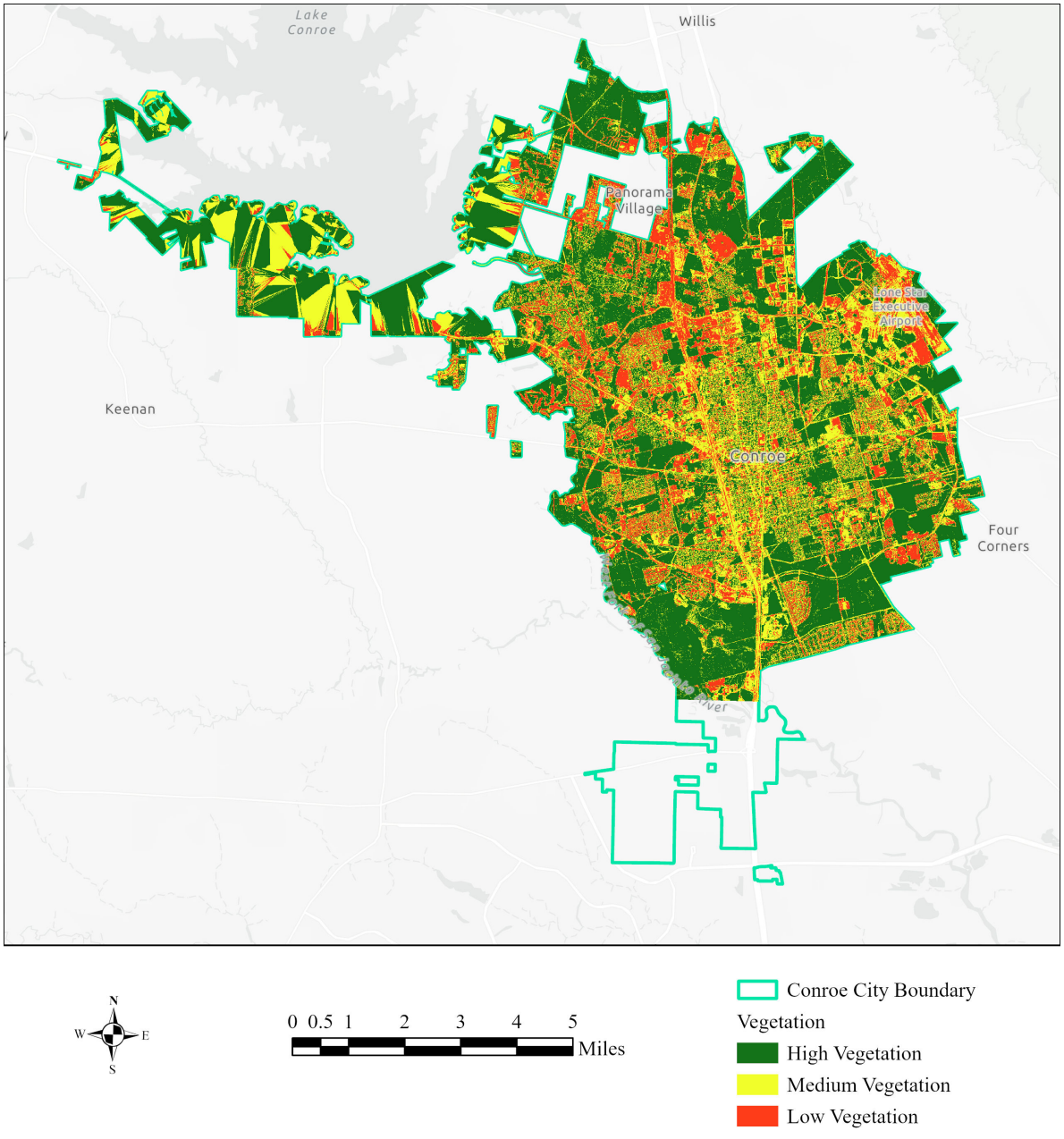


Figure 1: Vegetation Intensity Map of Conroe City

Color	Value	Label	Count
Vegetation		3 Values	
	1	High Vegetation	895434
	2	Medium Vegetation	516167
	3	Low Vegetation	321217

Figure 2: Vegetation Intensity Level Raster Cell Count Attribute Table

The results of the vegetation canopy analysis in Conroe, TX, reveal the spatial distribution and percentage of vegetation classified into three categories: high vegetation, medium vegetation, and low vegetation. Below is a detailed breakdown of the findings.

i) Vegetation Categories

The reclassified raster divided vegetation into three categories based on their intensity values:

- **High Vegetation (Green)**:
  - Representing dense and healthy vegetation, such as large trees and forests.
  - Total Count: **895,434 pixels**.
- **Medium Vegetation (Yellow)**:
  - Representing less dense vegetation, such as smaller trees, shrubs, and transitional areas.
  - Total Count: **516,167 pixels**.
- **Low Vegetation (Red)**:
  - Representing sparse vegetation or bare land with little to no green cover.
  - Total Count: **321,217 pixels**.

ii) Total Pixel Area

Each pixel in the raster represents a square area of **100 square meters** (10m x 10m cell size). The total number of pixels in the city boundary was calculated by summing all three categories:

- Total Pixels: **1,732,818 pixels**.
- Total Area: **173,281,800 square meters** (or **173.28 square kilometers**).

iii) Percentage Distribution of Vegetation Types

The percentage of each vegetation type was calculated using the formula:

$$\text{Percentage} = \left(\frac{\text{Pixels in Category}}{\text{Total Pixels}} \right) \times 100$$

- **High Vegetation (Green):**

$$\text{Percentage} = \left(\frac{895,434}{1,732,818} \right) \times 100 = 51.68\%$$

  - This represents **51.68%** of Conroe's total area.

- **Medium Vegetation (Yellow):**

$$\text{Percentage} = \left(\frac{516,167}{1,732,818} \right) \times 100 = 29.78\%$$

  - This represents **29.78%** of the city's total area.

- **Low Vegetation (Red):**

$$\text{Percentage} = \left(\frac{321,217}{1,732,818} \right) \times 100 = 18.54\%$$

  - This represents **18.54%** of the city's total area.

iv) Spatial Distribution

The spatial distribution of vegetation is visualized on the final map:

- **High Vegetation (Green)**:
    - These areas are concentrated around the outskirts of the city, particularly near **Lake Conroe** and other natural landscapes.
    - They represent the densest and healthiest vegetation zones.
- **Medium Vegetation (Yellow)**:
    - Found scattered throughout the city in smaller patches.
    - These areas often serve as transitional zones between dense vegetation and urban areas.
- **Low Vegetation (Red)**:
    - Primarily located in the urban core of Conroe.
    - These areas represent developed land with sparse vegetation, such as roads, buildings, and open spaces.

v) **Key Insights**

a) **High Vegetation (51.68%)**:
    - The majority of the city's vegetation is dense and healthy, particularly in less developed areas and natural reserves.
    - These zones are critical for ecological benefits, such as cooling, air purification, and biodiversity conservation.

b) **Medium Vegetation (29.78%)**:
    - These areas likely include smaller trees, shrubs, or grasslands, contributing moderately to the city's green space.
    - They provide some ecological and aesthetic benefits but could be targeted for reforestation or densification.

c) **Low Vegetation (18.54%)**:
    - A significant portion of the city lacks sufficient vegetation, particularly in urbanized zones.
    - These areas represent opportunities for urban greening projects, such as planting trees, creating parks, or expanding green corridors.

DISCUSSION

a) Comparison with Green Space Standards

The population of Conroe is **108,248**. According to the World Health Organization (WHO), urban areas should have at least **9 square meters of green space per person** to ensure a healthy and sustainable living environment (Wolch et al., 2014). Using this standard, Conroe would need approximately:

108,248×9 = 974,232 square meters (or 0.97 square kilometers)

The analysis shows that **51.68%** of Conroe's total area, approximately **89.54 square kilometers**, is densely vegetated. This far exceeds the WHO's minimum green space requirement. However, it is important to note that the distribution of green spaces is uneven. The majority of densely vegetated areas are concentrated in the outskirts near natural reserves like **Lake Conroe**, while the urban core has significantly lower vegetation density.

Although Conroe as a whole surpasses the minimum green space standards, efforts should focus on ensuring that these green spaces are equitably distributed so that residents in more urbanized zones also have access to vegetation.

b) Recommendations

i. **Enhance Urban Core Vegetation**:
   - Areas in the urban core with low vegetation density (18.54% of the city's area) should be prioritized for urban greening projects. Strategies could include planting street trees, creating green corridors, and developing small urban parks to make green spaces accessible to city residents.

ii. **Preserve and Protect High Vegetation Areas**:
   - The densely vegetated areas (51.68% of the city) near the outskirts should be preserved. These zones provide critical ecological benefits, such as reducing

urban heat islands, improving air quality, and supporting biodiversity. Conservation policies and monitoring programs could help maintain these areas.

iii. **Convert Medium Vegetation to High Vegetation**:
   - Medium vegetation zones (29.78% of the city) represent areas with potential for reforestation or densification. Initiatives such as community tree-planting drives or habitat restoration could enhance these zones, increasing their ecological value.

iv. **Improve Accessibility to Green Spaces**:
   - Ensure that residents in all parts of Conroe, especially in densely populated urban zones, have access to green spaces. This can be achieved by expanding public parks and implementing policies to require green spaces in new urban developments.

v. **Integrate Vegetation into Urban Planning**:
   - Future city development plans should incorporate green infrastructure, such as green roofs, vertical gardens, and sustainable landscaping, to integrate vegetation into urbanized areas without compromising development.

CONCLUSION

This project analyzed vegetation canopy and green space in Conroe, TX, using LiDAR data and GIS tools. The results show that 51.68% of Conroe's area is covered by dense vegetation, mostly located near natural areas like Lake Conroe and the city's outskirts. Medium vegetation makes up 29.78%, while areas with sparse or no vegetation account for 18.54% of the city's total area.

The findings highlight that Conroe, as a whole, has more than enough green space to meet the World Health Organization's recommendation of 9 square meters of green space per person. However, the vegetation is not evenly distributed. The urban core has significantly lower vegetation coverage compared to the outskirts, which could affect the quality of life for residents in densely populated areas.

Preserving the existing green spaces and increasing vegetation in low-vegetation areas, especially in the urban core, can help make Conroe a more sustainable and livable city. By focusing on urban greening projects, expanding parks, and protecting dense vegetation areas, the city can

continue to benefit from the ecological and social advantages of green spaces. These efforts will not only improve the environment but also enhance the well-being of all Conroe residents.

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